MEASUREMENTS OF THE INTENSITY OF TURBULENCE IN A GAS FLOW BY THE THERMOELECTRIC METHOD

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A thermoelectric method for measuring velocity fluctuations and turbulence in a gas flow, by determining the fluctuating portion of the dynamic component of the stagnation temperature at constant recovery factor, is described, with a flow diagram of the device. The method is applicable to measurements in pilot and full-scale installations and permits filtering out the velocity fluctuations from the temperature fluctuations.

The Institute of Technical Thermophysics of the Ukraine Academy of Sciences has developed a thermoelectric method of measuring the velocity fluctuations in a gas flow. The stagnation temperature for a flow with velocity fluctuation (Bibl.1) is

$$T' = T + r \frac{A}{2g \cdot c_p} \cdot (\overline{w} + w')^2,$$ (1)

where

$\overline{w}$ = steady mean velocity of the flow at some point;

w' = variable (fluctuating) velocity component.

The measurements of the turbulence intensity and velocity fluctuations are reduced to measuring the fluctuating part of the dynamic component of the stagnation temperature. In this case, the recovery coefficient r for each point of the flow will be considered constant.

Figure 1 shows a block diagram of the measuring device. The sensor is a

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* Numbers in the margin indicate pagination in the original foreign text.

low-inertia thermocouple (1) into whose circuit the inertialess PBZT-3 thermometer (2) is connected in series (Bibl.4) which compensates the lag in readings during rapid temperature fluctuations. The results are displayed on a N-700 loop oscillograph (4). An electronic low-frequency S1-4 oscillograph (3) is used for adjusting the circuit and for visual observation of the process. The temperature limits of the investigated flow are determined by the thermoelectric properties of the thermocouple.
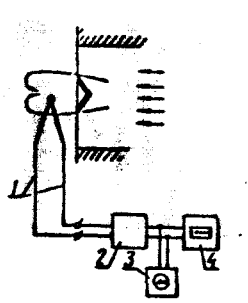

Fig.1 Block Diagram of the
Measuring Device

The circuit is tuned to specific measuring conditions. In eq.(1) the first and second terms $T + \dfrac{A}{2g \cdot c_p} \cdot \overline{w}^2$ characterize the overall temperature level of the flow for a specific point, while the expression $\dfrac{A}{2g \cdot c_p} (2\overline{w}\,w' + w'^2)$ represents the fluctuating portion of the dynamic component of the stagnation temperature of the flow.

The electric signal, characterizing the overall temperature level, is compensated by the reference voltage of the controller of the PBZT-3 instrument, thus establishing a tentative null line. Only the fluctuating component is measured relative to the null line.

The time constant of the thermocouple for the instantaneous velocity value is

$$\epsilon = \frac{\gamma \cdot V}{S} \cdot \frac{c_p}{a}$$

(2)

2

where

> γ, c_p, V, S = specific weight, specific heat, volume, and surface of
> the thermocouple;
>
> α = heat transfer coefficient between the thermocouple and the
> flow washing it.

The heat transfer coefficient depends to a considerable extent on the rate of flow past the thermocouple. Hence it follows that the time constant of the thermocouple placed in a turbulent flow will continuously vary, decreasing with an increase in velocity and vice versa.

During operation of a thermocouple with a compensating instrument and abrupt temperature changes on the surface of the thermocouple, the character of the output signal is determined by the equation (Bibl.5)

$$u = U + U \cdot \frac{RC - \epsilon}{\epsilon} \cdot e^{-\frac{\tau}{\epsilon}}. \tag{3}$$

Here,

> u = output signal of the measuring device;
>
> U = emf corresponding to the measured temperature (in this case, stagnation temperature of the fluctuating velocity component of the flow);
>
> τ = current time of the measuring process.

At $RC > \epsilon$ (Bibl.5) there will be a "burst" of the signal whose magnitude depends on the ratio $\frac{RC - \epsilon}{\epsilon}$; the larger this ratio, the greater the burst.

Thus, the actions of the shaping network, when correcting the signals of the thermocouple, coincide in sign with the variations in the fluctuating ve- /33 locity component. As a result, the signals are greatly amplified toward the corresponding changes.

In the measurement, the time constant of the thermocouple is first approximately determined after which the value of the RC parameters at which the fluc-

tuation signals are most distinct and prominent is defined in the storage of the differentiator. It was established experimentally that RC should be greater than ε by a factor of 3 - 5. Depending upon the measuring conditions, this ratio can be varied to either side.

Thus, the signal is amplified in the amplifier units of the instrument and by overcompensation.
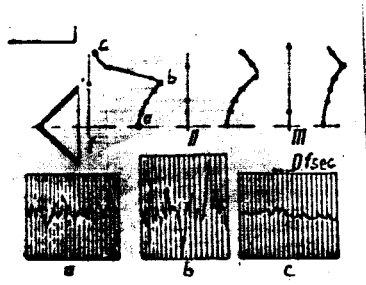

Fig.2 Turbulence Intensity Downstream
of a U-Shaped Stabilizer and
Oscillograms for the Points a, b, c.

The oscillograms (Fig.2) show the curves of the time rate of change of the fluctuating velocity component. These tracings are interpreted by the method proposed at the V.I.Lenin All-Union Order of Lenin Electrical Engineering Institute, consisting in a determination of the root-mean-square amplitude for each point of the flow.

The curves for turbulence intensity are obtained with the above method by feeding a U-shaped stabilizer of 32 mm width with a steady air stream having the parameters w = 50 m/sec and t = 85°C for the cross sections I - III. Four additional stabilizers were exposed to the air jet, and the curves of the turbulence intensity for each were obtained.

The results of an experimental check of the method agree well with the results of hot-wire anemometry under equal conditions (Bibl.2, 3).

The measuring device was calibrated by means of calibration grids, and the calibration curves were plotted for each thermocouple. This yields a quantitative picture of the intensity of turbulence.

The measuring probe is simple in design and manufacture and can be of any configuration and size.

Individual components of a turbulent flow can be investigated by using butt-welded thermocouples (Bibl.2, 3). In this case, the thermocouple must be placed into the flow in a prescribed manner so as to vary the conditions of flow past it.

The test circuit is easily and quickly tuned to various operating conditions.

The measuring device is small, simple to operate, and is characterized by high accuracy of measurement and stability of the performance characteristics.

An electronic unit can be switched into the measuring device, for averaging the magnitude of the fluctuating signals and for reading the level of turbulence intensity for each point of the flow at a specified scale.

The thermoelectric method of measuring turbulence intensity and velocity fluctuations in a gas flow is based on the low inertia of the test circuit and amplification of the signal of only the fluctuating velocity component while operating under overcompensating conditions.

The thermoelectric method can be used for investigating turbulence and velocity fluctuations of a gas flow in various experimental and full-scale installations.

A major advantage of the method is the possibility of experimentally investigating flows at high temperatures, with the limit given only by the heat resistance of the thermocouples. Furthermore, it has been established experi-

mentally that, under specific experimental conditions, the thermoelectric method permits filtering out the velocity fluctuations from the temperature fluctuations.

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